TISA Working Group Report

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CERES Science Team Meeting

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Outline

- Introduction to TISA
- GEO calibration
- GEO image quality control
- SSF1deg-month Ed3 and Ed4 comparison over 5-years
- SYN1deg-month Ed3 and Ed4 comparison over 6-months
- TISA Ed4 deliveries and Future efforts

Introduction

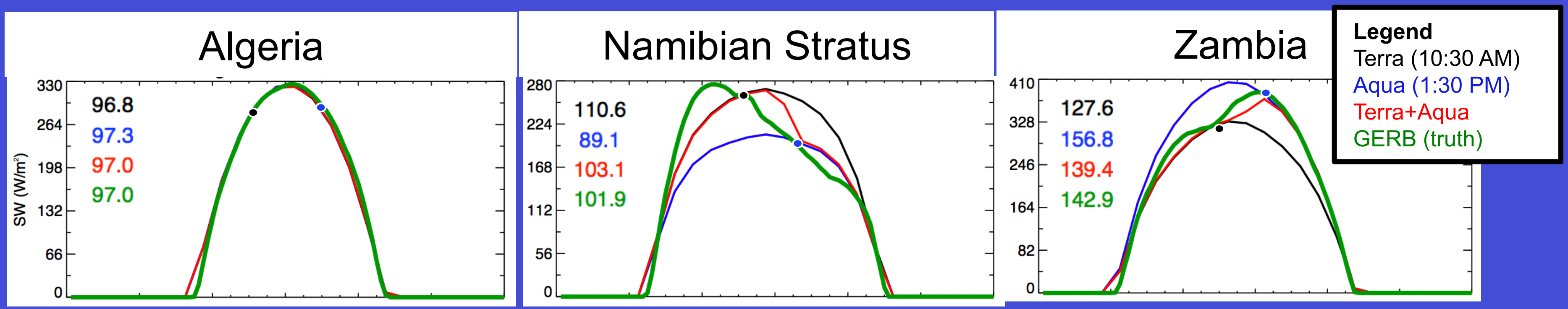
- CERES is onboard the Terra (10:30 AM local equator crossing time), Aqua (1:30 PM), and NPP (1:30 PM) platforms
- The CERES 20-km nominal footprint fluxes are instantaneously averaged in 1° by 1° regions
  - The CERES footprint radiances are converted to fluxes using the CERES ADMs based on imager cloud properties and GMAO MERRA atmosphere
- The regional diurnal flux in between CERES measurements needs to be estimated to derive accurate daily mean fluxes
- The daily regional fluxes are then spatially and temporally averaged into CERES level 3 products
  - To produce monthly global, zonal, and regional fluxes over the 15-year CERES record

CERES level 3 data products

- **SSF1deg**, assumes constant or linear changing meteorology between CERES measurements to model the diurnal cycle
  - Single satellite products
- **SYN1deg**, uses geostationary derived broadband fluxes between CERES observations to model the diurnal cycle
  - Terra+Aqua+NPP product
- **EBAF-TOA**, combines the stability of the SSF1deg product and the accuracy of the regional daily flux means of the SYN1deg product and removes all known flux biases
  - The TOA net flux is constrained to the ocean heat storage
  - The clear-sky fluxes are spatially complete, by computing sub-footprint clear-sky fluxes using the MODIS pixel radiances
  - This product allows climate modelers to validate their fluxes with CERES

SSF1deg CERES-only (CO) SW product

- SW: assume the observed clouds are constant over the day and accounting only for changes in the sun position using a solar zenith angle dependent albedo models based on scene type

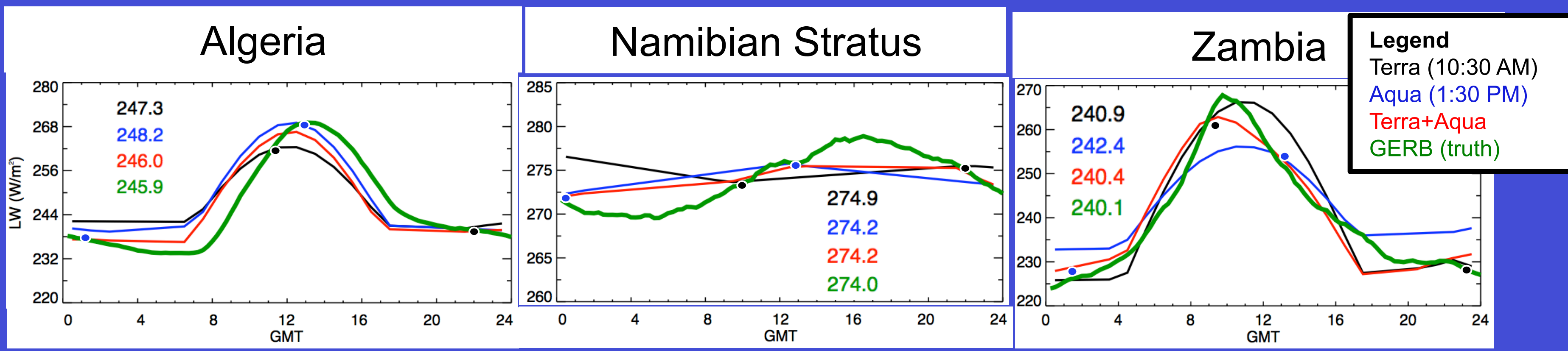


- The clear-sky desert SW fluxes over deserts are symmetric about noon and all datasets capture the diurnal cycle
- The stratus and land convection monthly mean dataset SW fluxes will be biased as a function of satellite sampling time

SSF1deg CERES-only (CO) LW product

– LW Ocean: linear interpolate LW fluxes in time

– LW Land: assume a half sine fit centered at noon to estimate the land heating and a constant nighttime LW flux

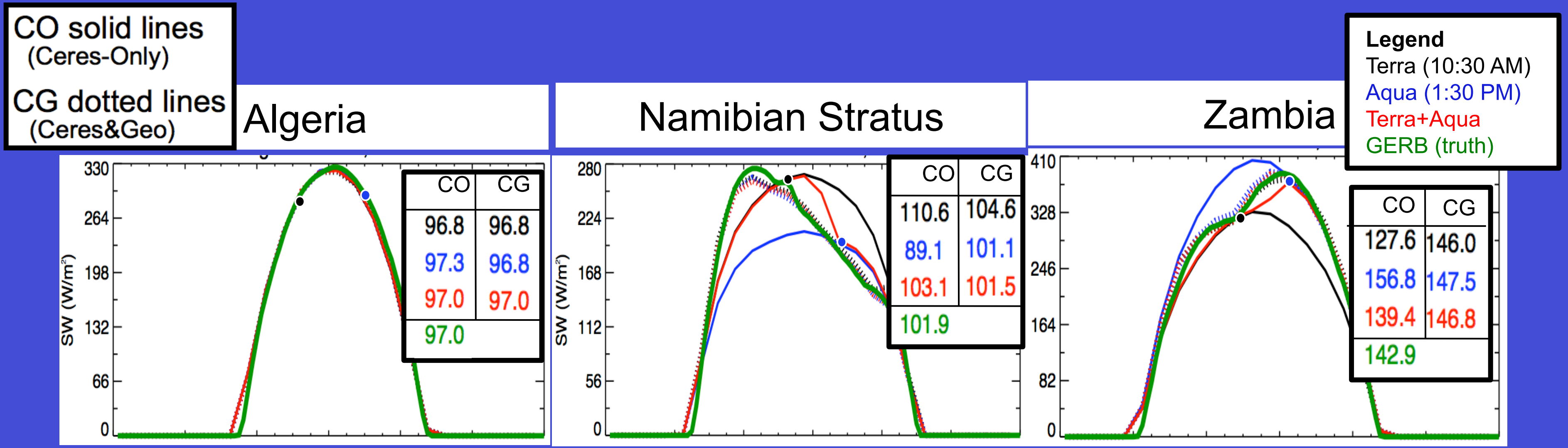


- GERB desert LW fluxes verify that land heating lags the solar cycle
- The monthly mean dataset LW fluxes are very close to GERB, however they do not replicate the true diurnal cycle

SYN1deg GEO enhanced Ed3 product TOA fluxes

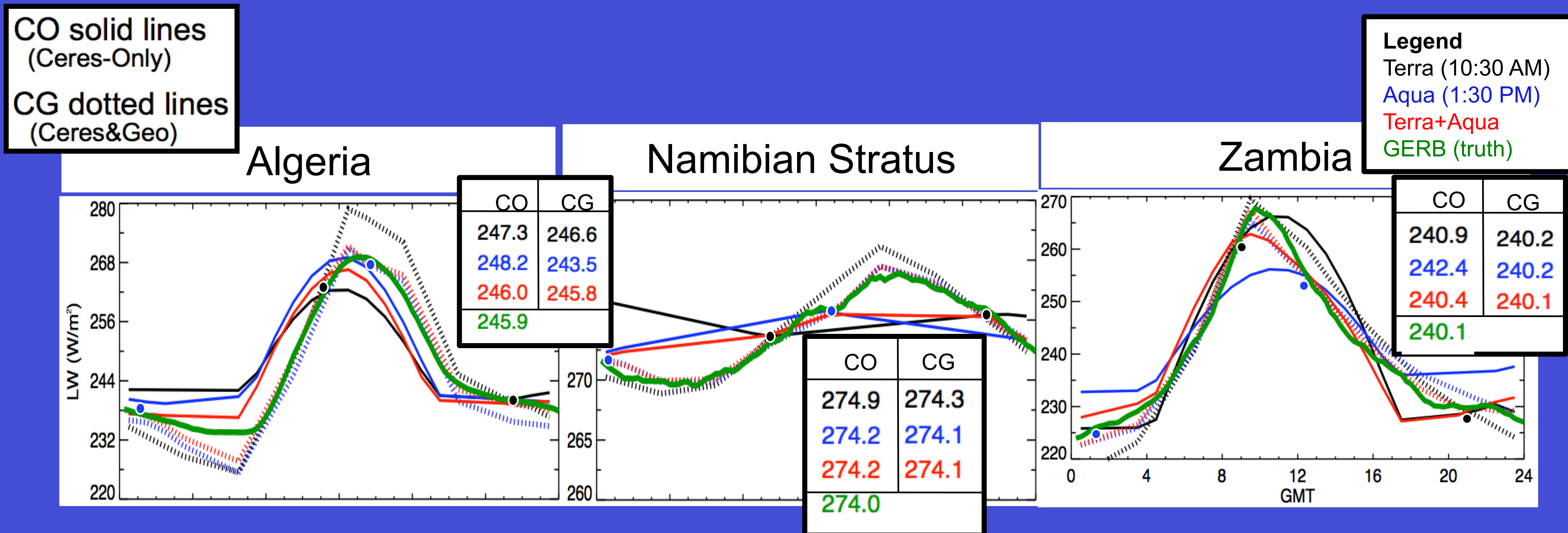
- Use 3-hourly 5-geostationary derived BB fluxes to estimate the diurnal flux signal in between CERES Terra and Aqua flux measurements to compute the daily mean fluxes
- Calibrate the GEO visible and IR radiances against MODIS in order to derive consistent GEO and MODIS cloud properties
- Convert GEO NB radiances to BB radiances using MODIS/ CERES empirical and theoretical models to account for spectral response based on GEO retrieved scene types
- Use the CERES ADMs to convert the GEO BB radiances into fluxes based on GEO retrieved scene types
- Regress coincident regional CERES and GEO flux pairs monthly to normalize the GEO BB fluxes with CERES to maintain the CERES instrument calibration

SYN1deg CERES+GEO (CG) SW product



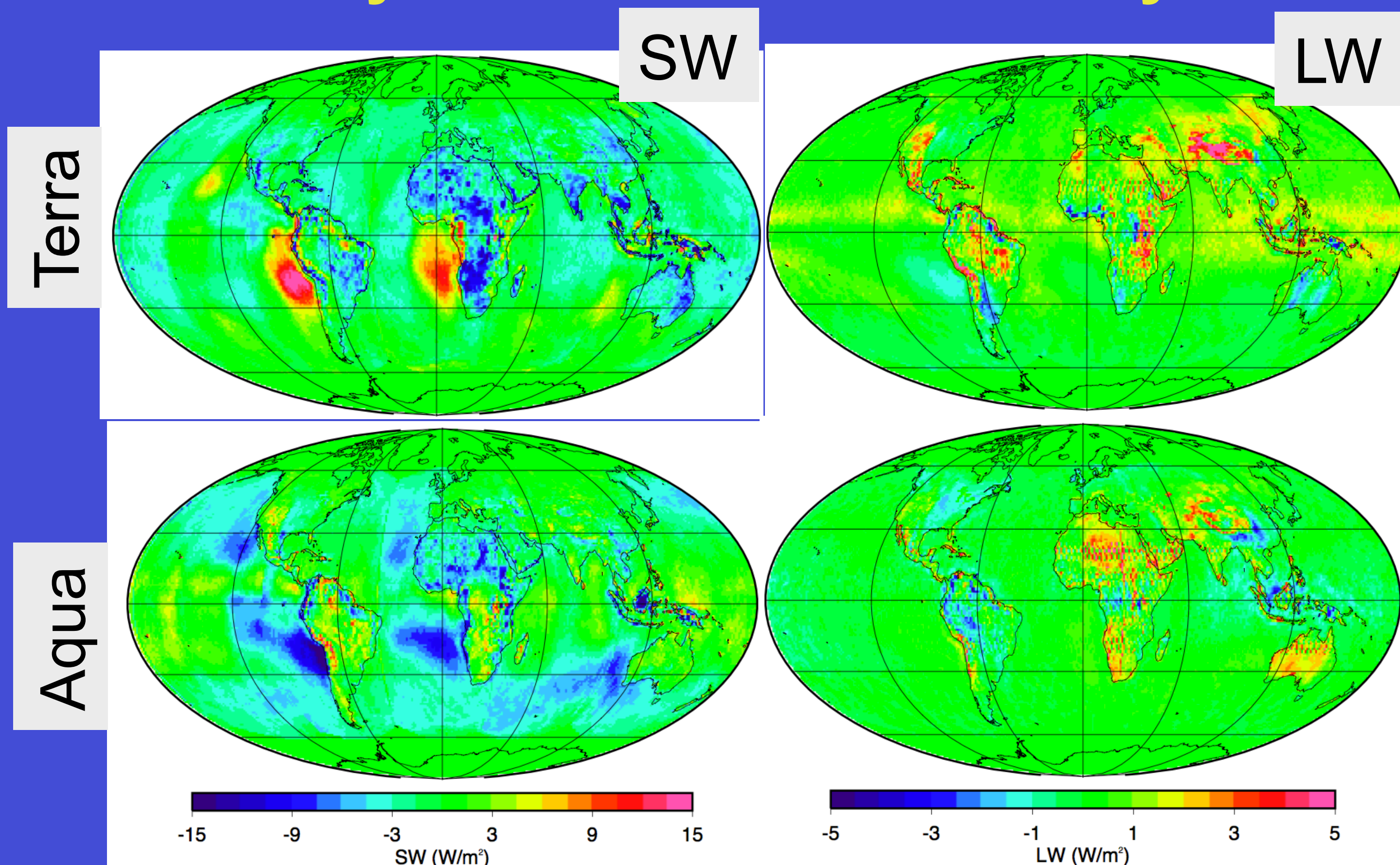
- The 3-hourly SW GEO derived BB fluxes replicate the GERB fluxes more accurately than CERES-only
- Terra+GEO and Aqua+GEO datasets are more consistent than Terra-only or Aqua-only
- A single satellite SW CERES+GEO dataset is an improvement over the Terra and Aqua CERES-only dataset

SYN1deg CERES+GEO (CG) LW product



- The CERES+GEO LW have a similar diurnal shape as GERB over stratus and land convection, however, over the desert the CERES+GEO has a greater diurnal amplitude
- All LW approaches have similar monthly means, but their diurnal shapes differ

CERES-Only minus CERES+GEO 9-year mean bias



Doelling et al. 2013

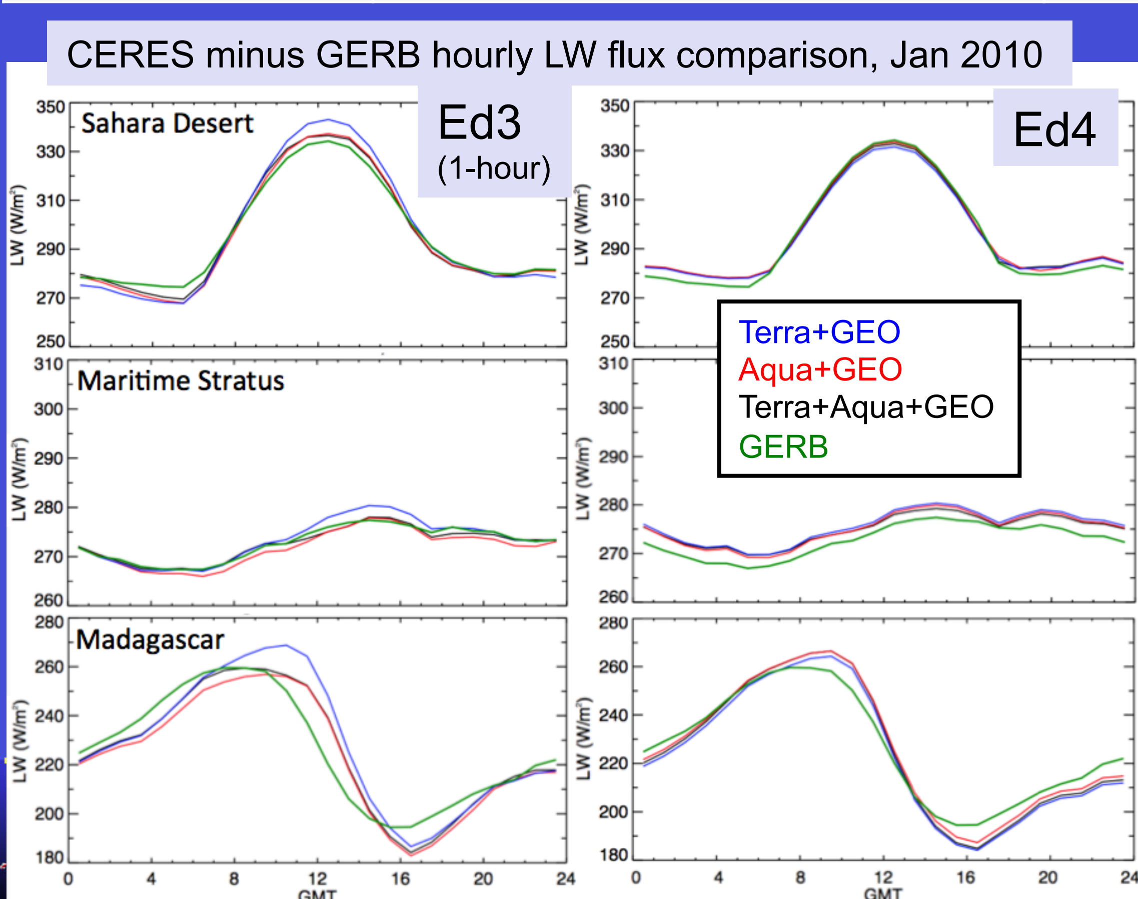
9-year global means (July 2002-June 2011)

	Terra		Aqua	
(Wm^{-2})	CO	CG	CO	CG
SW	96.6	97.7	96.4	97.7
LW	239.4	238.9	238.9	238.8
Net	4.4	3.7	5.0	3.8

- 9-year regional differences can be as large as 25 and 8 Wm^{-2} in the SW and LW respectively
- However, accounting for the diurnal cycle only changes the global SW flux +1.2 Wm^{-2}, neither Terra or Aqua capture both the maritime stratus or land convection
- The global LW flux difference is within 0.5 Wm^{-2}

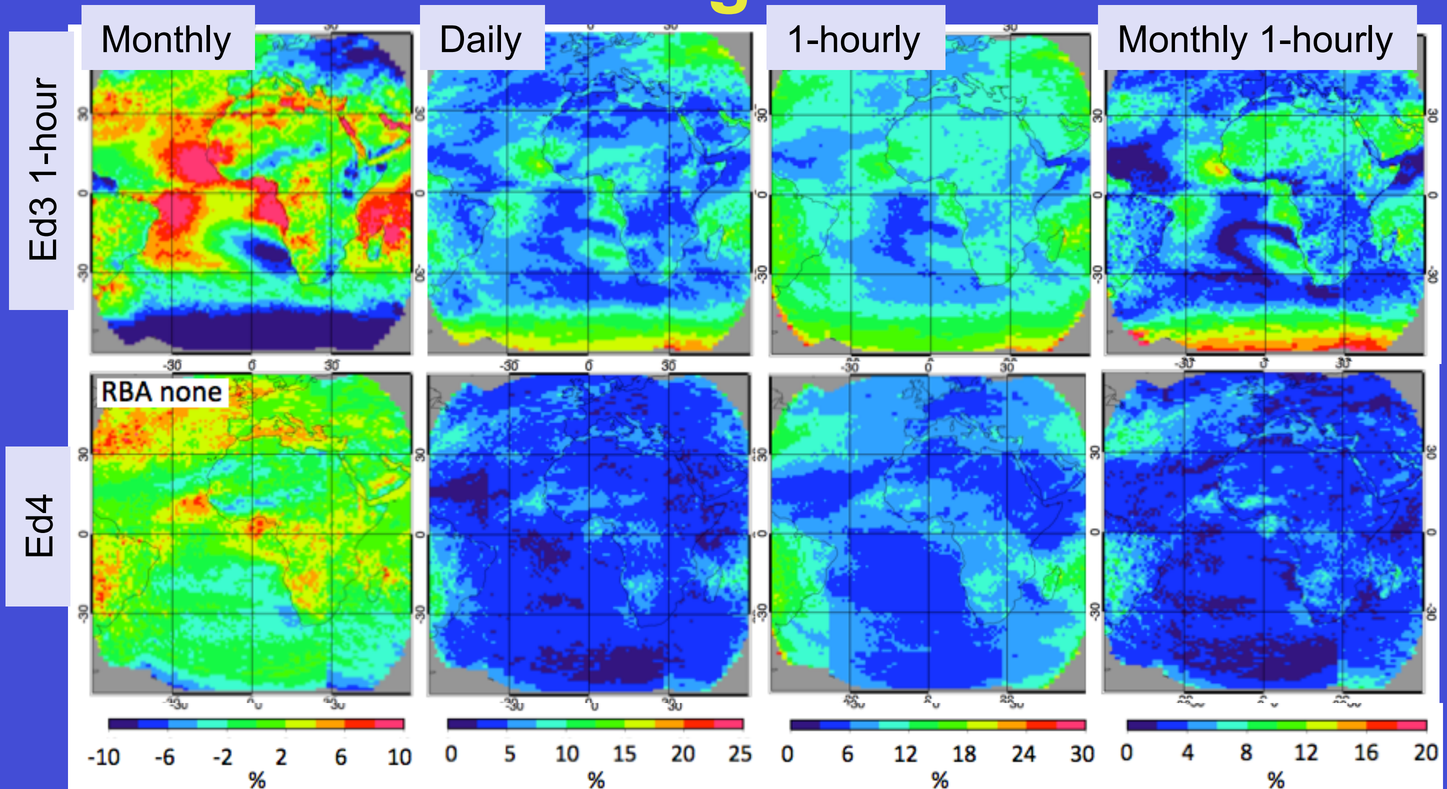
Improved GEO-derived LW fluxes for CERES Edition 4 reprocessing

Parameter	Edition 3	Edition 4
GEO sampling	3-hourly	1-hourly
LW NB to BB	11µm radiance and column weighted from GEOS-4/5	Use the 6.7µm and 11µm radiance



- With regional normalization the Ed4 CERES+GEO LW fluxes are more consistent than the Ed3 LW fluxes
- This implies that the GEO LW fluxes are more accurate for Ed4 algorithm
- This will provide consistent SYN1deg LW fluxes when Terra instrument fails and the CERES relies only on the 1:30 local time orbits

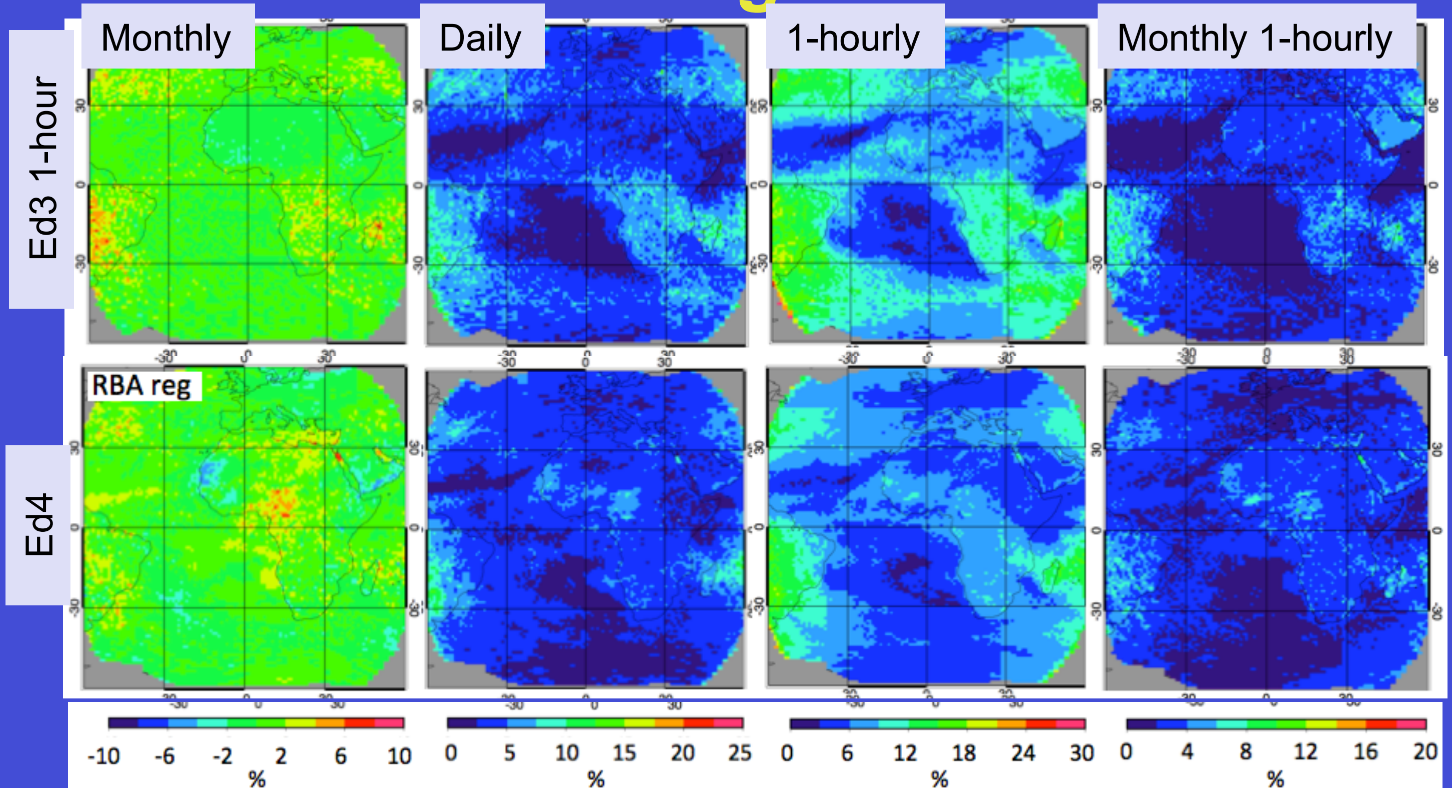
CERES+GEO LW minus GERB hourly fluxes Jan 2010 no regional normalization



%	Bias	Monthly RMS	Daily RMS	3-hour RMS	1-hour RMS	Monthly 3-hour	Monthly 1-hour
Ed3	0.21	2.19	2.94	3.86	4.14	2.41	2.49
Ed4	0.20	0.99	1.72	2.62	2.95	1.26	1.39

- Observed 6.7μm and 11μm calibrated against MODIS is more effective than the assimilated GEOS water vapor

CERES+GEO LW minus GERB hourly fluxes Jan 2010 *with* regional normalization



%	Bias	Monthly RMS	Daily RMS	3-hour RMS	1-hour RMS	Monthly 3-hour	Monthly 1-hour
Ed3	0.19	0.53	1.85	3.26	3.61	1.03	1.20
Ed4	0.14	0.59	1.54	2.48	2.81	0.97	1.12

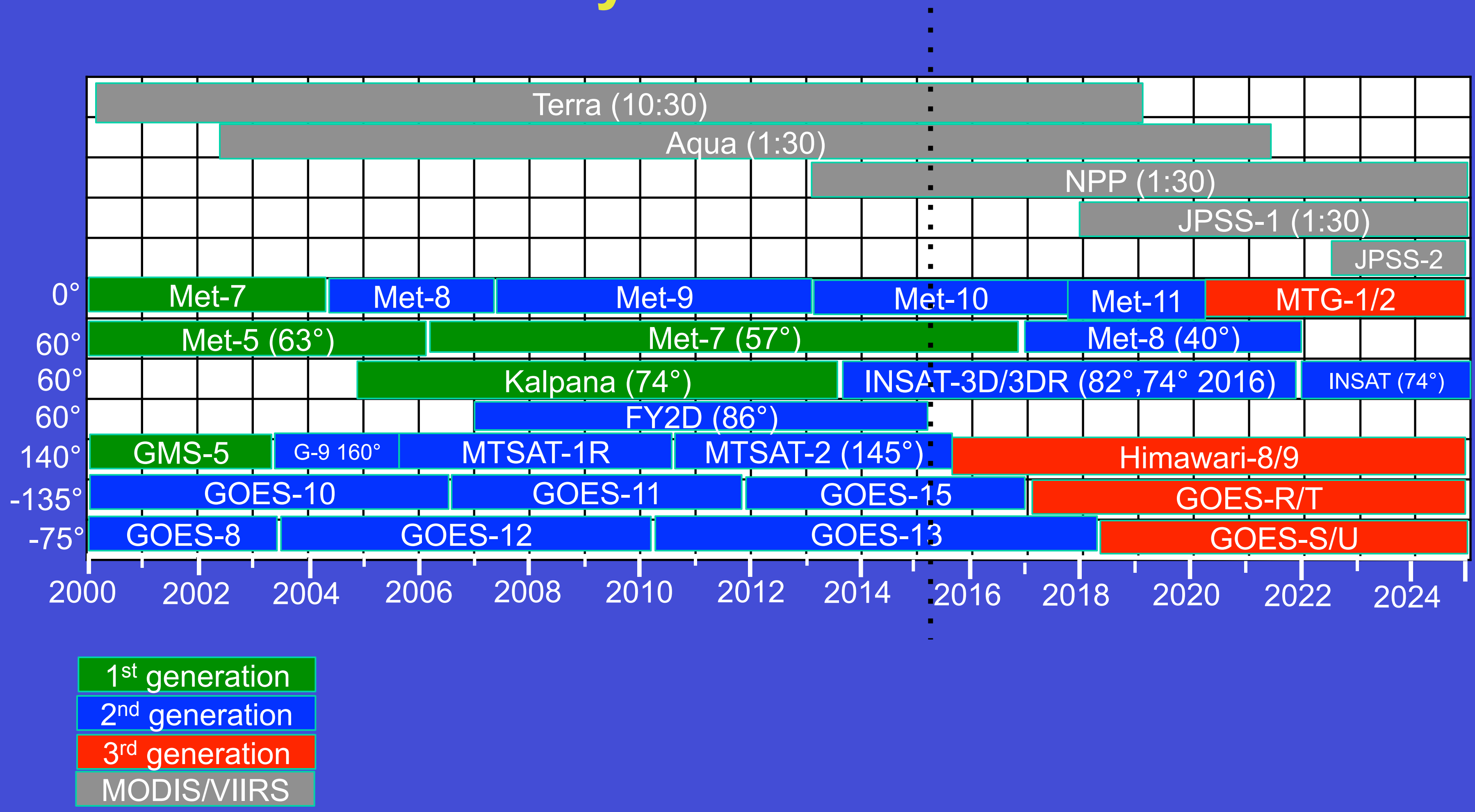
- With CERES regional flux normalization reduces the overall RMS errors
- Ed4 is an improvement over Ed3 for all temporal resolutions except monthly means

GEO CALIBRATION

Geostationary Update

- Meteosat-11 (0°E) successfully launches August 10, 2015
  - Will replace Meteosat-10 in March 2018, currently in standby mode
- Meteosat-8 (40°E) to replace Meteosat-7 (57°E) in November 2016
  - Meteosat-7 will be decommisioned
- Himawari-8 (140°E) becomes operational July 6, 2015
  - CERES Ed4 to begin processing from July 2015
- GOES-R (16) (135°W) to launch in March 2016
  - Operational no earlier than 4-6 months after launch
- FY-2G (105°E) is available on McIDAS, since June 3, 2015
  - Replaced FY-2E (105°E)
  - FY2E (86°E) is now the primary China-West position
  - FY2D (86°E) has been decommisioned
- INSAT-3D available on McIDAS from Nov 2014 to present
  - CERES Ed4 to begin processing from Nov 2014

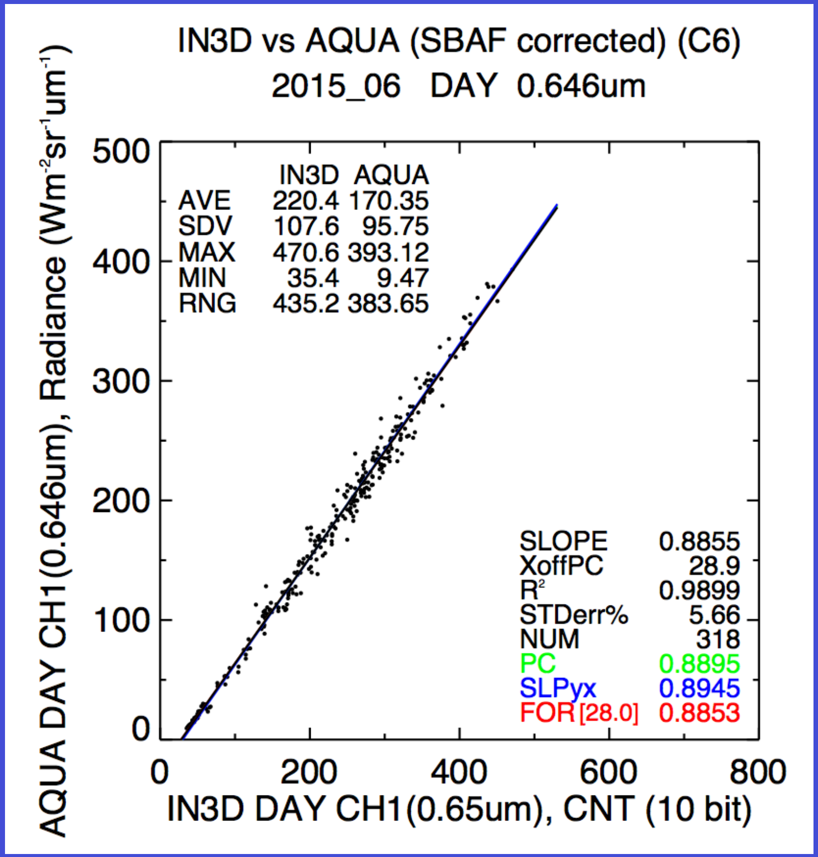
Geostationary Satellite Time Series

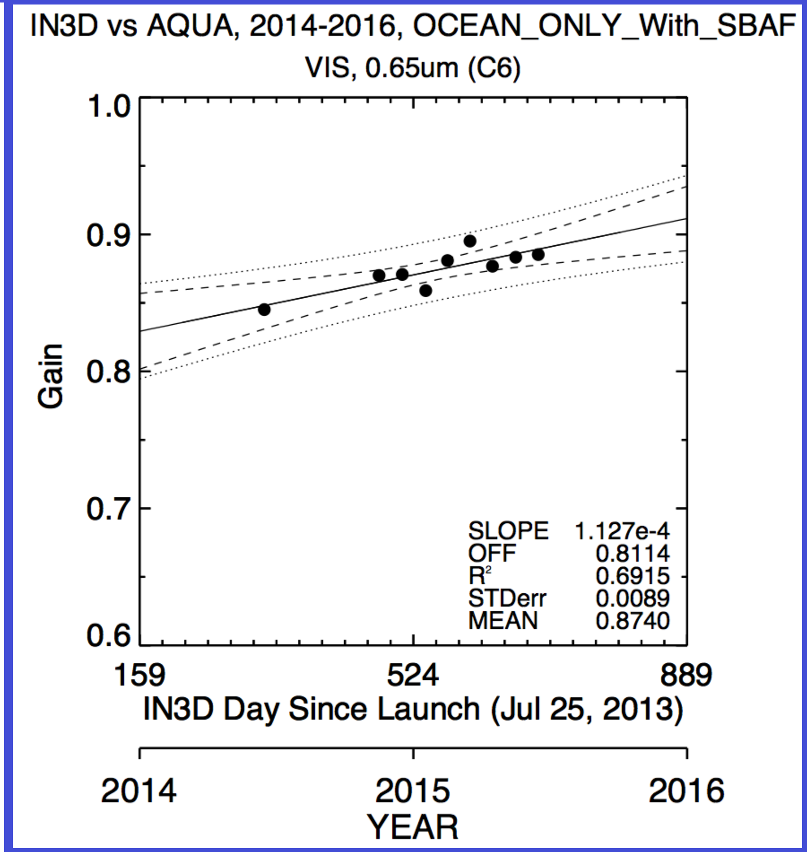


INSAT-3D

- Launched July 25, 2013 at 82° East
  - Operational from Jan 16, 2014 till 2021
  - Second INSAT-3DR to be launched in 2015 at 74° East with same imager as INSAT-3D
- First Indian 2nd generation imager satellite
  - 0.65µm, 1.6µm, 3.9µm, 6.8µm, 10.8µm, 12µm
- McIDAS record starts in November 2014 to present
  - Collaborative effort between IMD, ISRO, McIDAS and CERES
  - Some data available from April 28, 2014
- Test imager calibration and sensor linearity against Aqua-MODIS

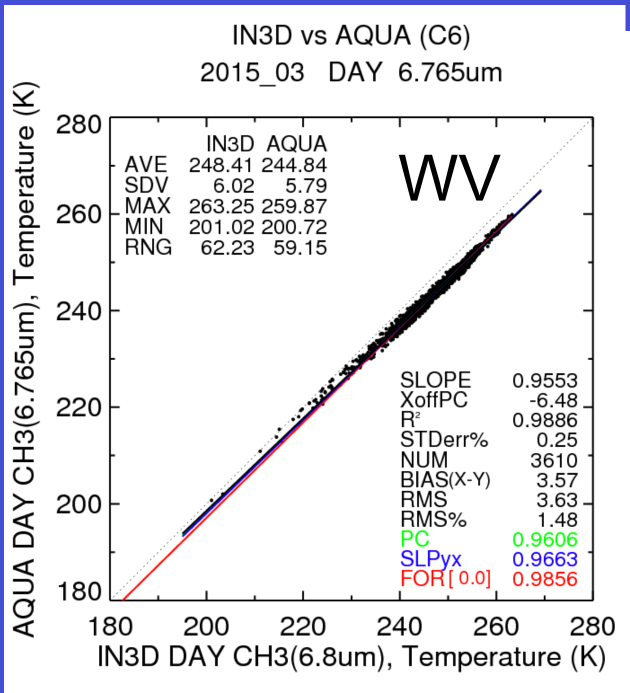
INSAT-3D/Aqua-MODIS 0.65µm channel

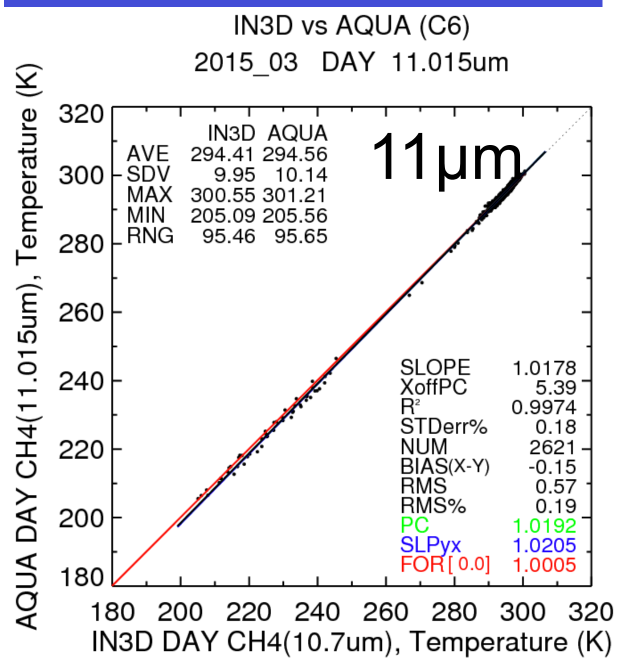


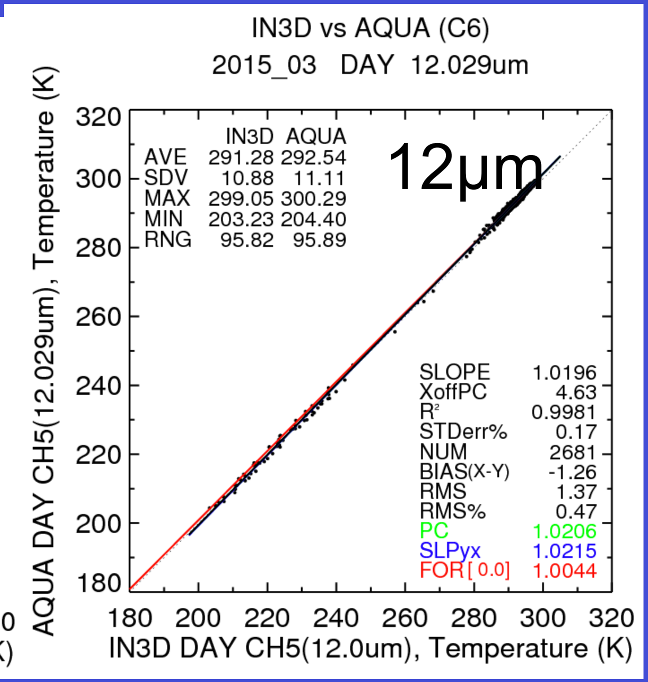


- November 2014 to present available at McIDAS
- The visible sensor is linear with respect to Aqua-MODIS band 1

INSAT-3D/Aqua-MODIS IR channels







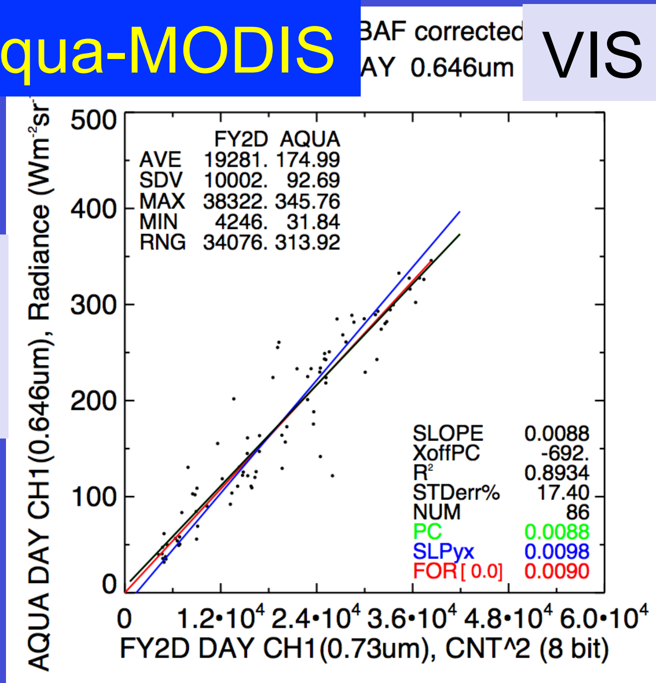
- IR channels are well calibrated
- No spectral response differences removed

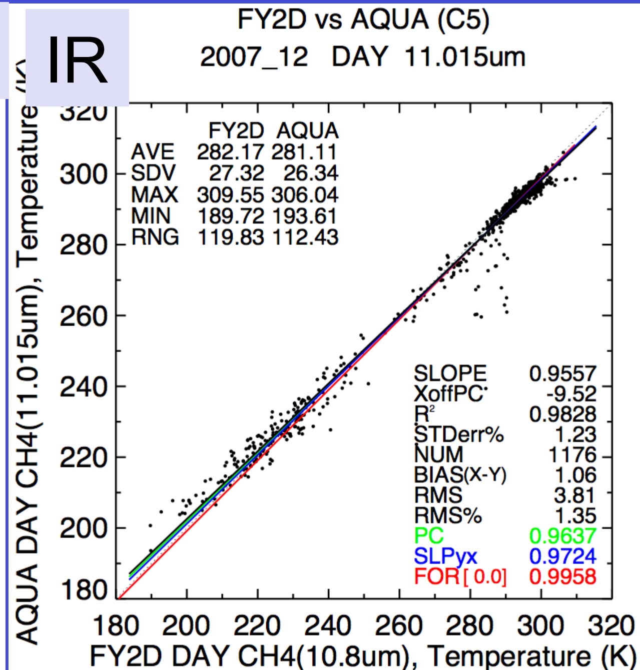
- CERES Ed4 processing will incorporate INSAT-3D beginning in November 2014

FY/Aqua-MODIS

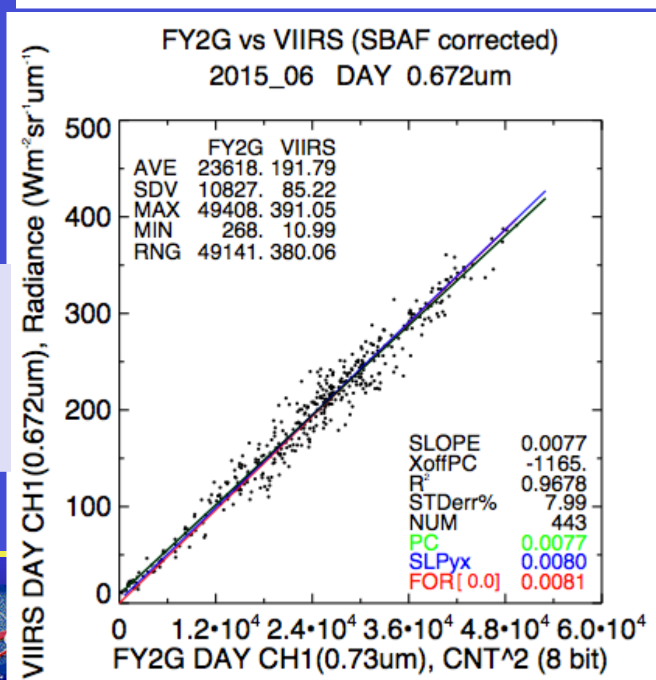
VIS IR

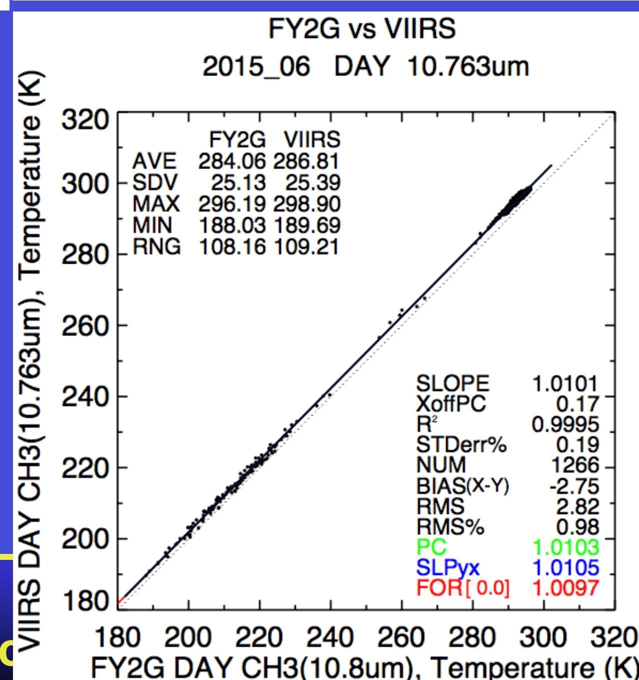
FY2D





FY2G





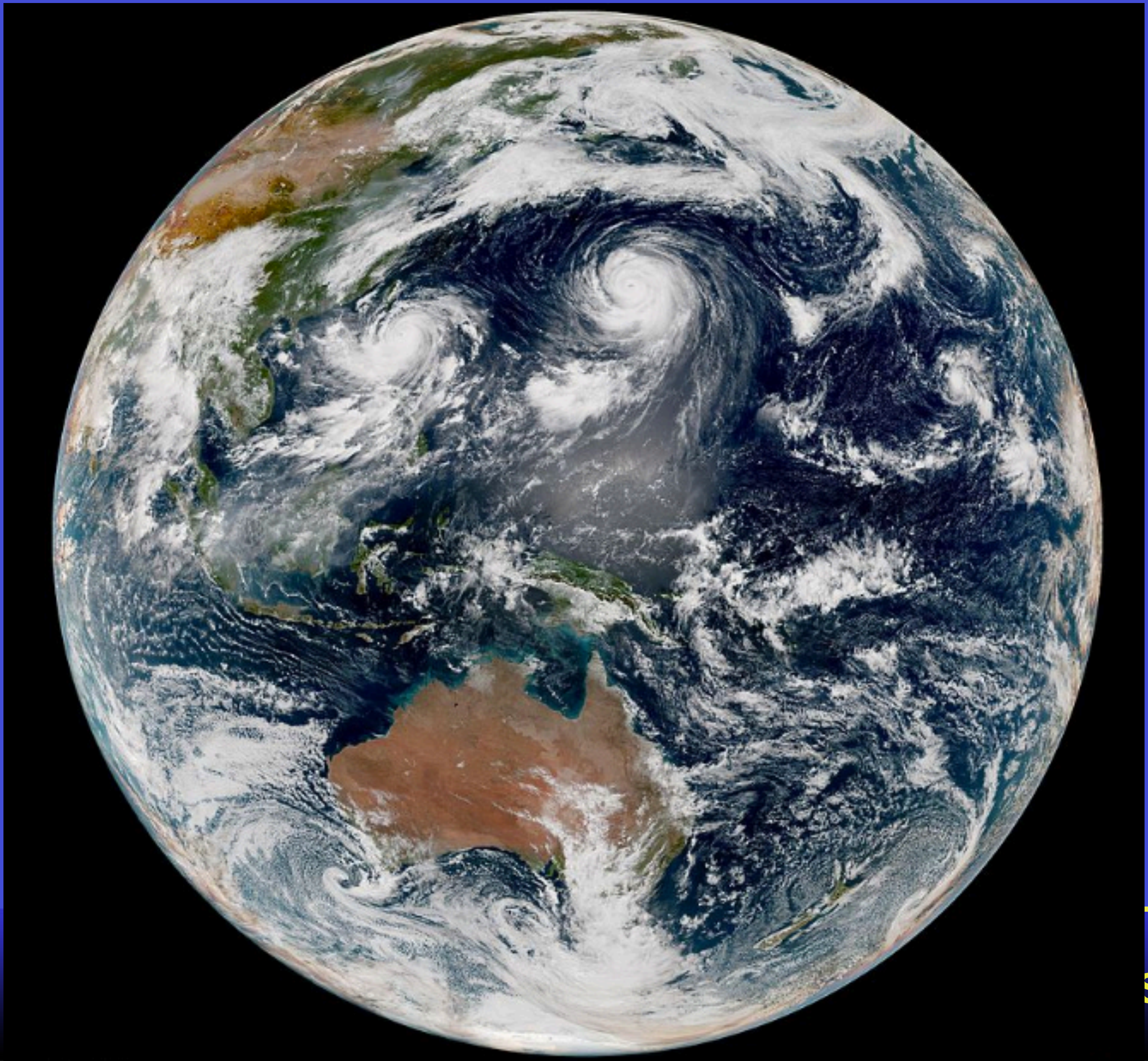
- The Chinese GEO quality continues to improve
- FY2G became operational in June 2015 at 105°E
- FY2E moved from 105°E to 86.5° E in June 2015
- FY2D became operational in Aug 2007 at 86.5°E, decommissioned in June 2015

Himawari-8

- Launched October 7, 2014, sub-satellite point 140°E
  - Operational from July 6, 2015 and projected to 2022
  - First 3rd generation GEO imager launched
  - Himawari-9 to launch in 2016
- Is very similar to the GOES-R imager
  - 16 channel imager, with bands similar to MODIS or VIIRS

  0.46, 0.55, 0.65, 0.86, 1.6, 2.25, 3.9, 6.3, 7.0, 7.4, 8.6, 9.6, 10.5, 11.2, 12.4, 13.3μm
  - GOES-R to launch in March 2016
- Test imager calibration and sensor linearity against NPP-VIIRS

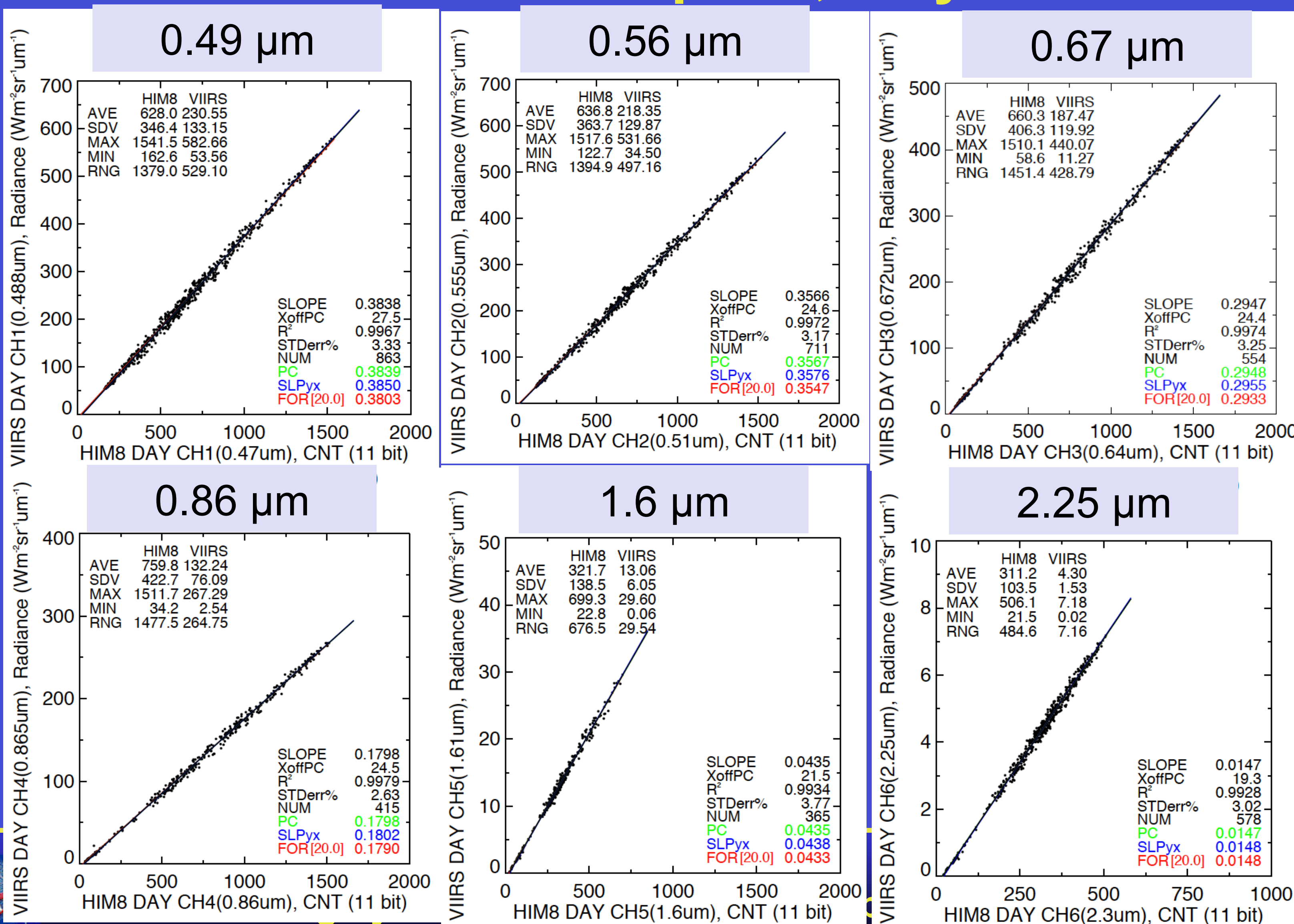
Himawari-8 Full Disc Scan



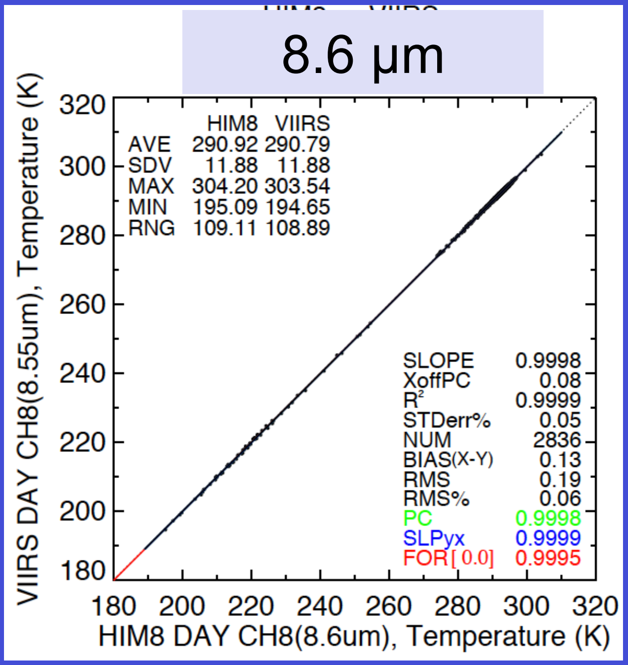
- Full disc scan every 10 minutes, performed in 2 minutes
- 0.5-km 0.65μm
- 1-km 0.46, 0.55 and 0.86 μm
- 2-km 1.6, 2.25, and all IR channels

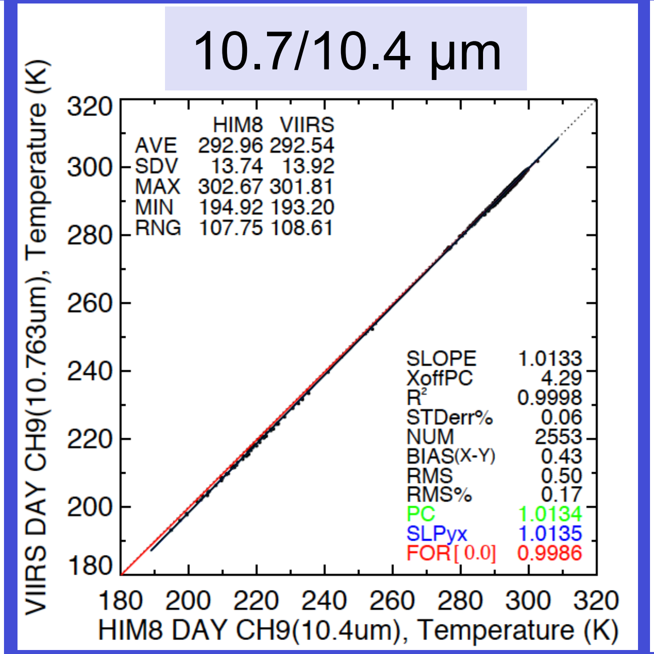
- 22000x22000 full disc pixel resolution for the red channel

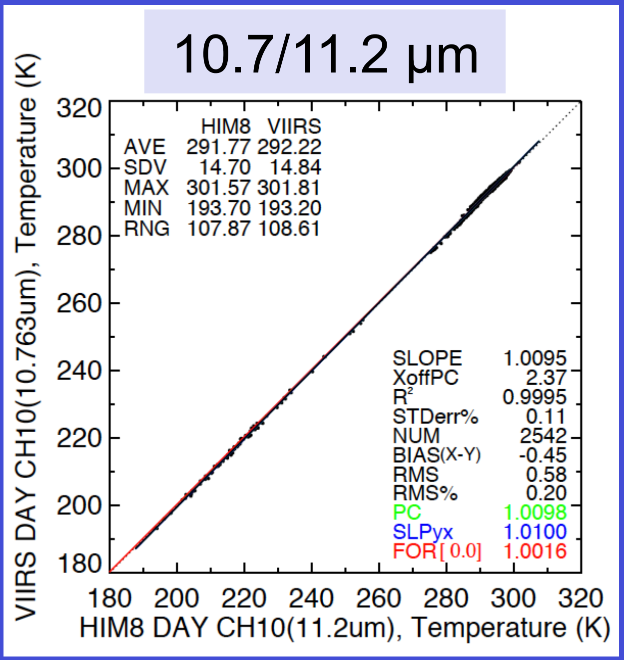
Himawari-8/NPP-VIIRS visible channel ray-matched radiance pairs, July 2015



Himawari-8/NPP-VIIRS window channel ray-matched radiance pairs, July 2015







- The Himawari-8 IR calibration is very similar to VIIRS, no spectral differences accounted for
- The Himawari-8 visible has a very linear sensor compared with VIIRS
- CERES Ed4 processing will incorporate Himawari-8 beginning in July 2015

Possible CERES improvements using Himawari-8 data

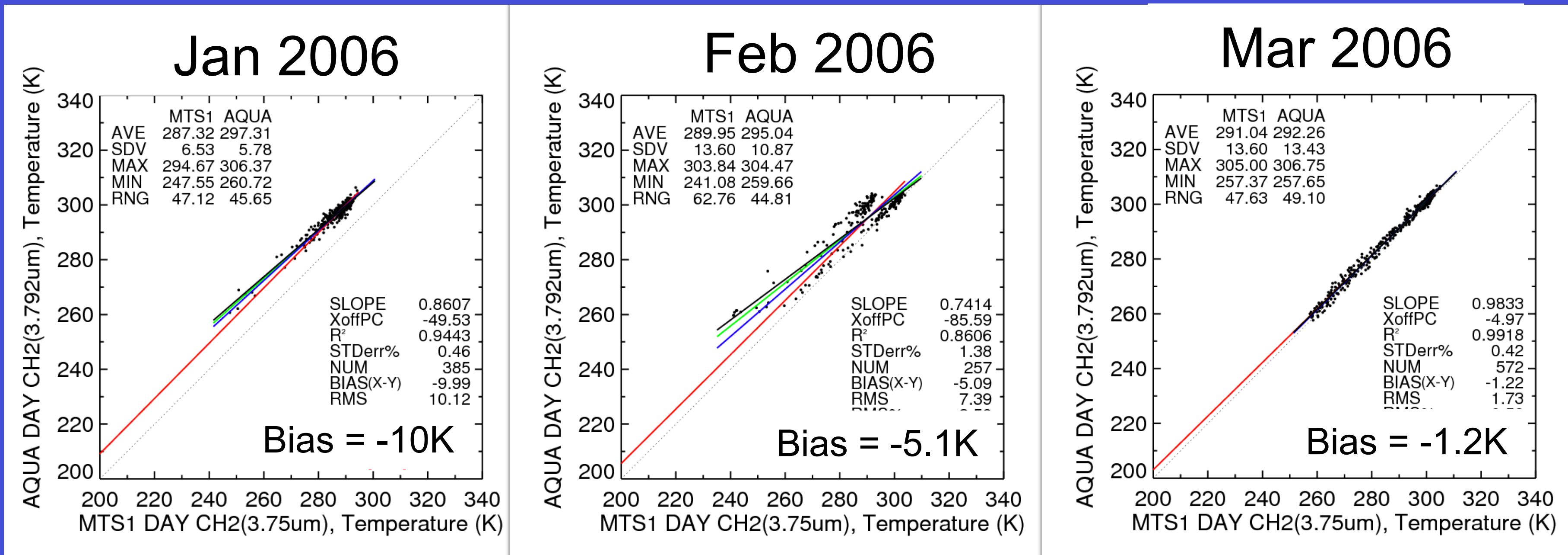
- Can apply MODIS/VIIRS Ed4 imager cloud algorithm
  - Using all MODIS or VIIRS channels
  - Can test the code at 2-km resolution, currently GEOs are processed at the 8-km resolution
  - This makes it possible for higher resolution 0.5° products
- Can test higher temporal resolution time-space averaging, currently using 1-hourly data
- Can test using more channels in the GEO narrowband to broadband algorithms
- Compare the Himawari-8 TOA and surface fluxes against Edition 4 data
  - First test MODIS-like cloud code retrievals with the current Ed4 TISA and SARB codes, then with improved GEO fluxes
  - Lastly test higher spatial and temporal resolution fluxes

GEO CLEANING

Ed4 GEO improvements

- 1-hourly GEO imager fluxes and cloud retrievals
  - Ed3 3-hourly GEO
- 4-channel GEO cloud retrievals
  - Ed3 2-channel GEO cloud retrievals
- Water Vapor channel used to derive LW TOA flux
  - Ed3 used column weighted relative humidity from GEOS-4
- GEO image quality control performed by automated bad scan line detection program and human bad scan line removal algorithm
  - Ed4 has 7 times the number of GEO images than Ed3
  - Ed3 post 2012 GEO image quality control performed by humans
  - Ed3 pre 2012 no GEO image quality control

MTSAT-1R 3.7µm temperature adjustment



- Feb 15, 2006 is when the 3.7µm was changed
- Before correction, the entire MTSAT-1R domain was cloudy at night
- This is a problem for the 4-channel code, which stopped processing during 2005, and prompted processing 2008 until this problem was solved
- 3.7µm correction: $T_{new} = 1.0261 \cdot T_{old} + 1.39$

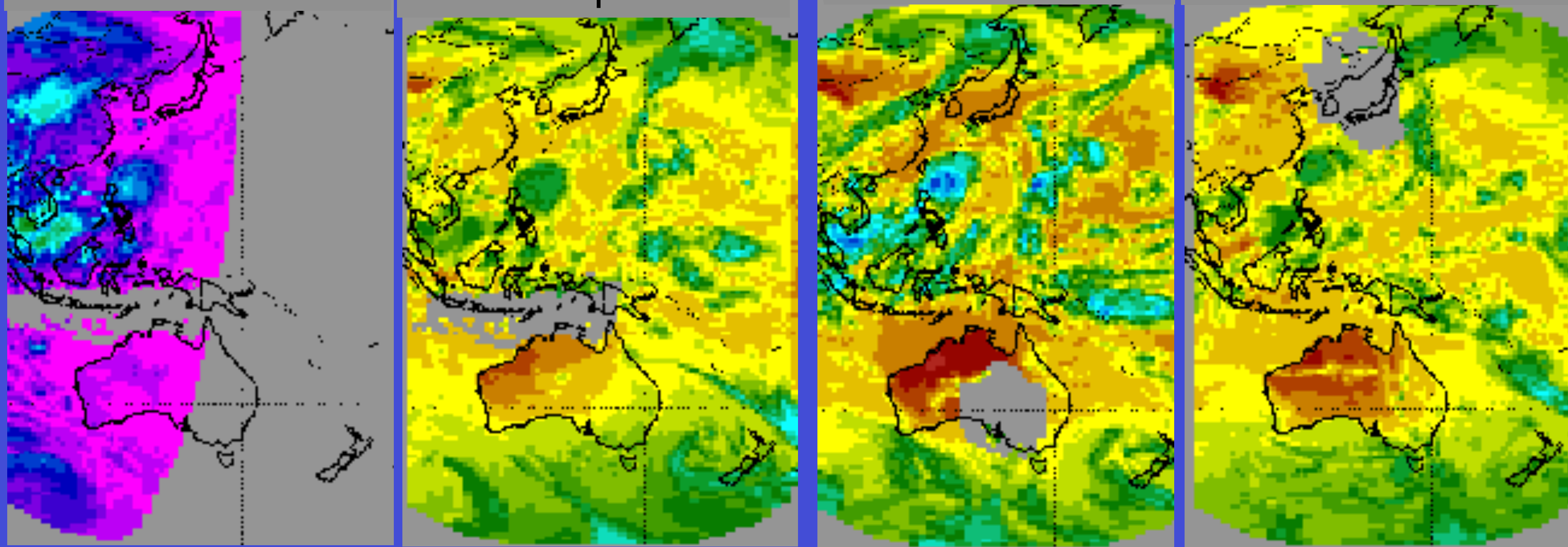
MTSAT-1R data drop out

Sept 9, 7 GMT

visible | 3.7µm

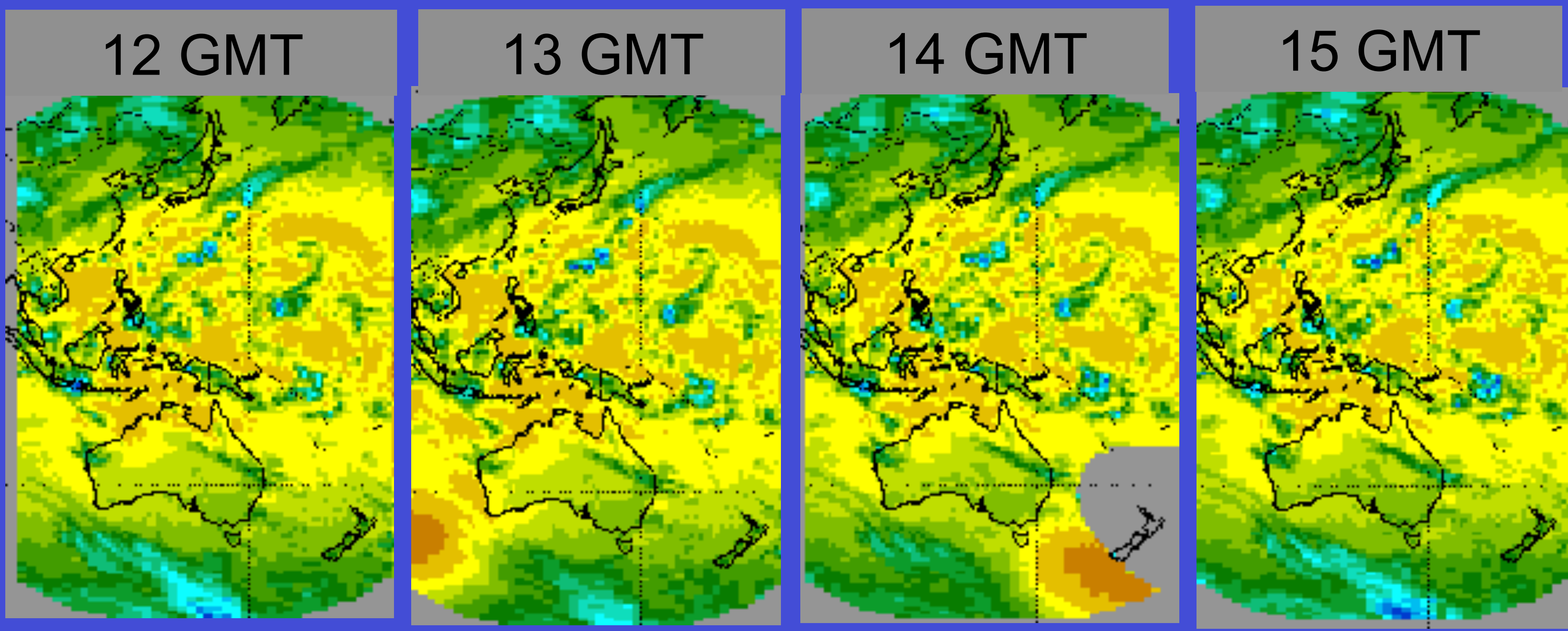
Sept 10, 6 GMT, 11µm

Sept 12, 6 GMT, 3.7µm



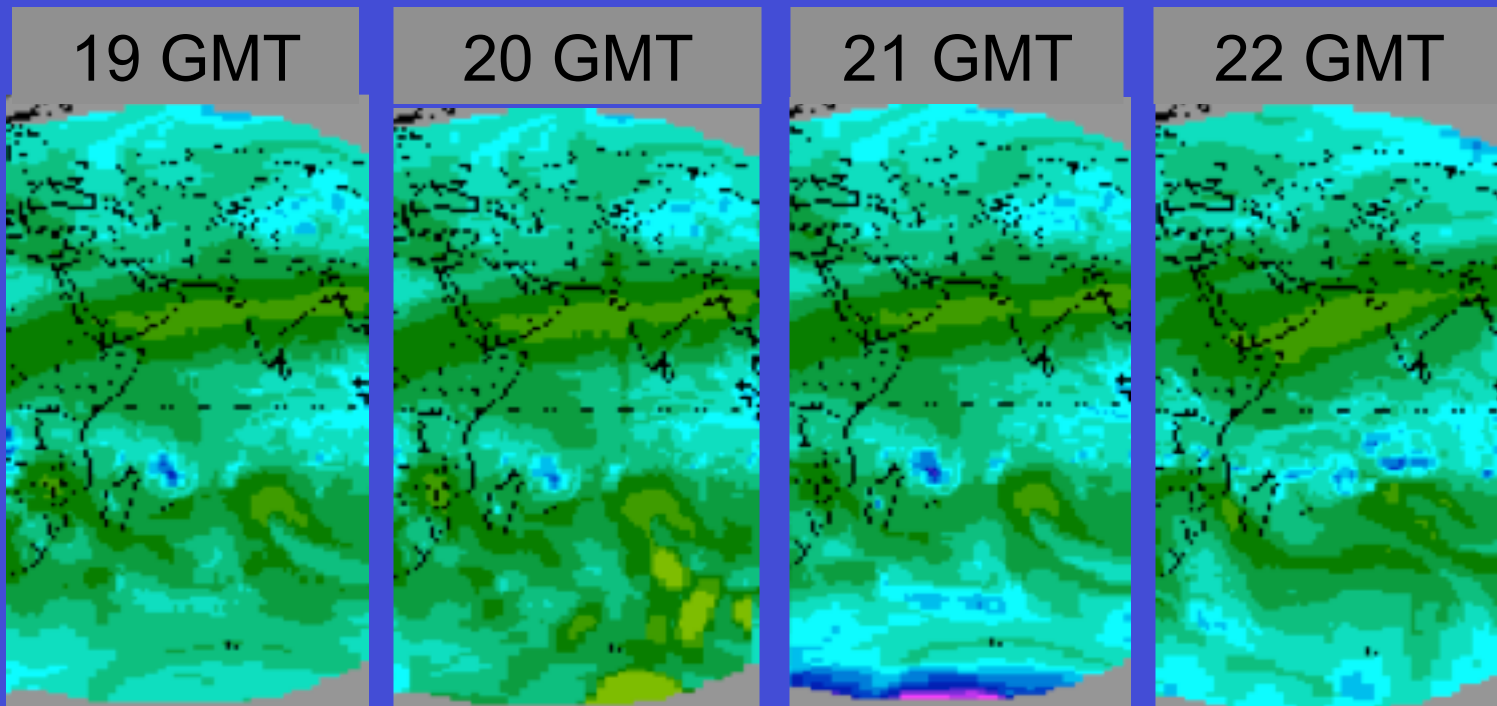
Linear features can easily be detected by Konstantin's program
Stray light banding, data drop out, or saturation is much harder

MTSAT-1R, 3.7μm channel, Oct 8, 2008, 12-15 GMT

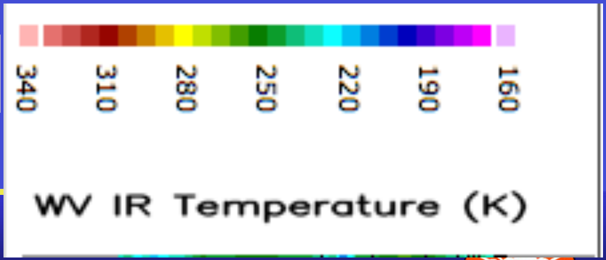


• Stray light impacts both the 13 and 14 GMT images

Met-7, WV channel, Feb 11, 2008; 19-22 GMT



- Stray light impacts both the 20 and 21 GMT images



GEO cleaning statistics for 2008

Number of images with bad scan lines

images	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GOES-E	25	42	6	7	12	13	6	4	0	37	10	4
GOES-W	6	4	6	10	24	23	22	21	11	0	13	24
Met-9	0	2	1	2	2	0	1	1	0	2	1	2
MTSAT-1	81	47	30	18	23	66	42	17	71	18	26	27
MET-7	1	32	33	10	6	16	9	37	36	14	2	7

Number of removed scan lines

scan lines	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GOESE	366	5096	746	20	14	33	12	13	0	298	717	53
GOESW	24	5	15	20	986	1430	50	69	11	0	15	33
MSG	0	1400	16	13	17	0	13	1	0	37	87	39
MTSAT	32381	8590	6253	4705	1945	6418	6506	1956	8848	6600	2897	3654

Number of unusable images

default	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GOESE	0	0	5	0	0	0	0	0	0	0	5	0
GOESW	0	11	0	0	0	0	0	0	0	0	0	0
MSG	0	6	0	0	0	0	0	0	0	0	0	0
MTSAT	144	2	11	20	0	5	1	0	0	0	0	0

Number of cloud code failure images (program bombed)

Cloud code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GOESE	7	6	6	7	9	3	7	9	2	13	13	8
GOESW	4	2	3	8	7	0	8	2	1	1	3	4
MSG	10	4	3	12	9	0	8	4	2	7	9	1
MTSAT	10	3	3	20	5	6	3	4	0	1	13	6

Number of un-scanned images (Eclipse avoidance)

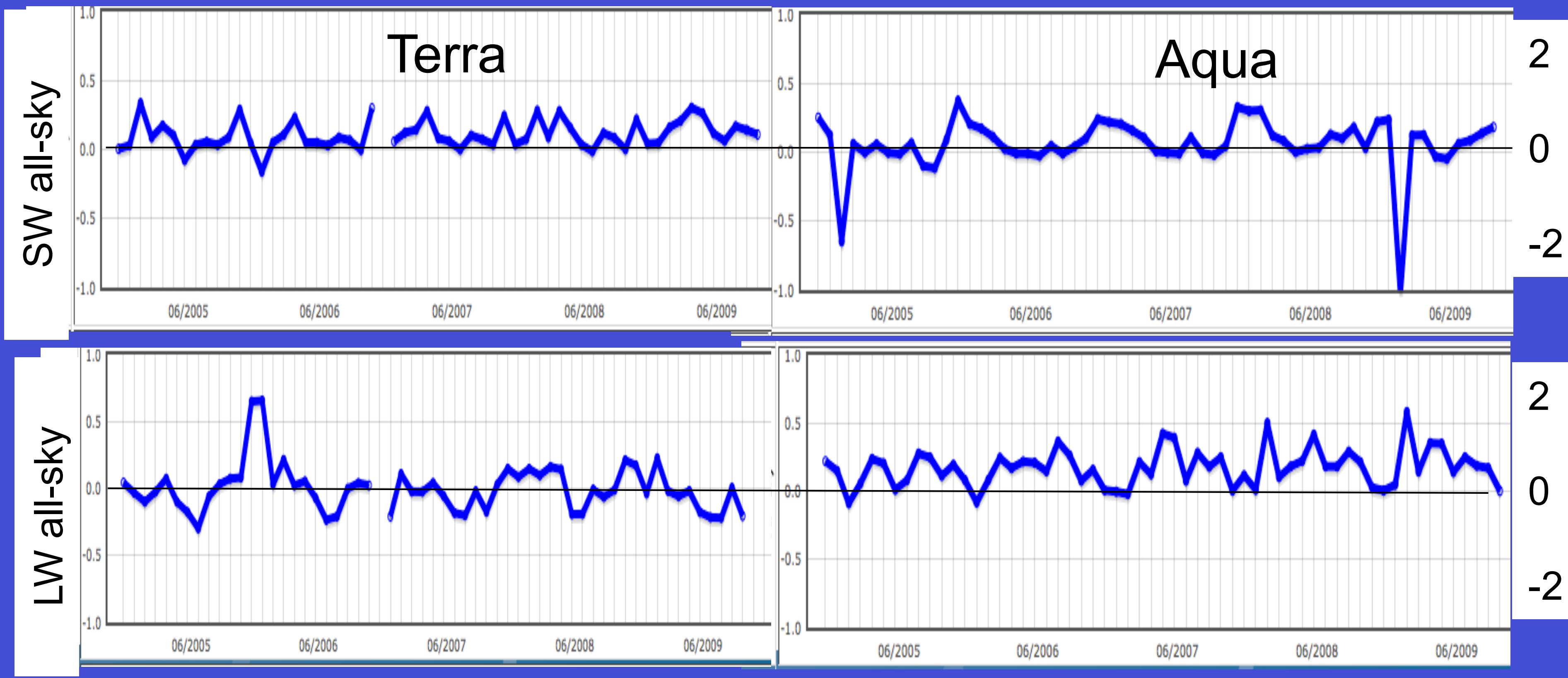
No Scan	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GOESE	1	20	64	63	2	1	0	40	74	35	1	11
GOESW	1	19	62	31	0	2	0	20	55	32	0	0
MSG	1	0	0	0	12	6	0	3	1	0	4	3
MTSAT	16	41	4	18	0	8	1	8	1	0	1	0

Ed4 GEO cleaning schedule

- 6 months of GEO imagery can be cleaned every week
  - Have cleaned 2008 and 1st half of 2009
  - Cleaning the 2nd half of 2009 this week
- Schedule
  - 2008 to 2010, then 2005 to 2007, Process for EBAF-TOA to determine the SW and LW calibration adjustments to maintain the net balance based on the ocean heat storage
  - 2000 to 2004, then 2011 to present
- EBAF period should be finished by early November
  - Run SYN1deg-lite off-line to keep schedule
- 14-years of processing should be finished by mid-March
  - Run by the DAAC

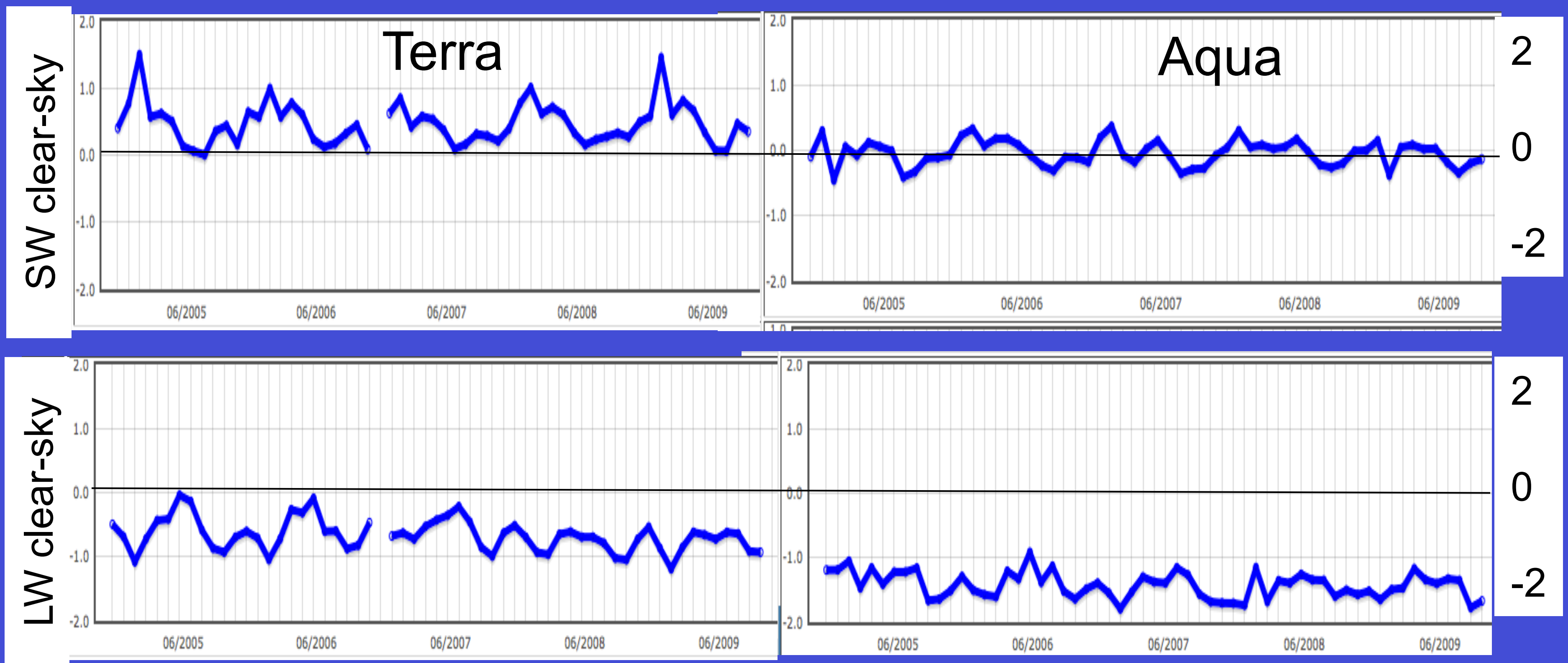
SSF1deg Ed3 – Ed4

SSF1deg-Month Ed3 minus Ed4 TOA fluxes



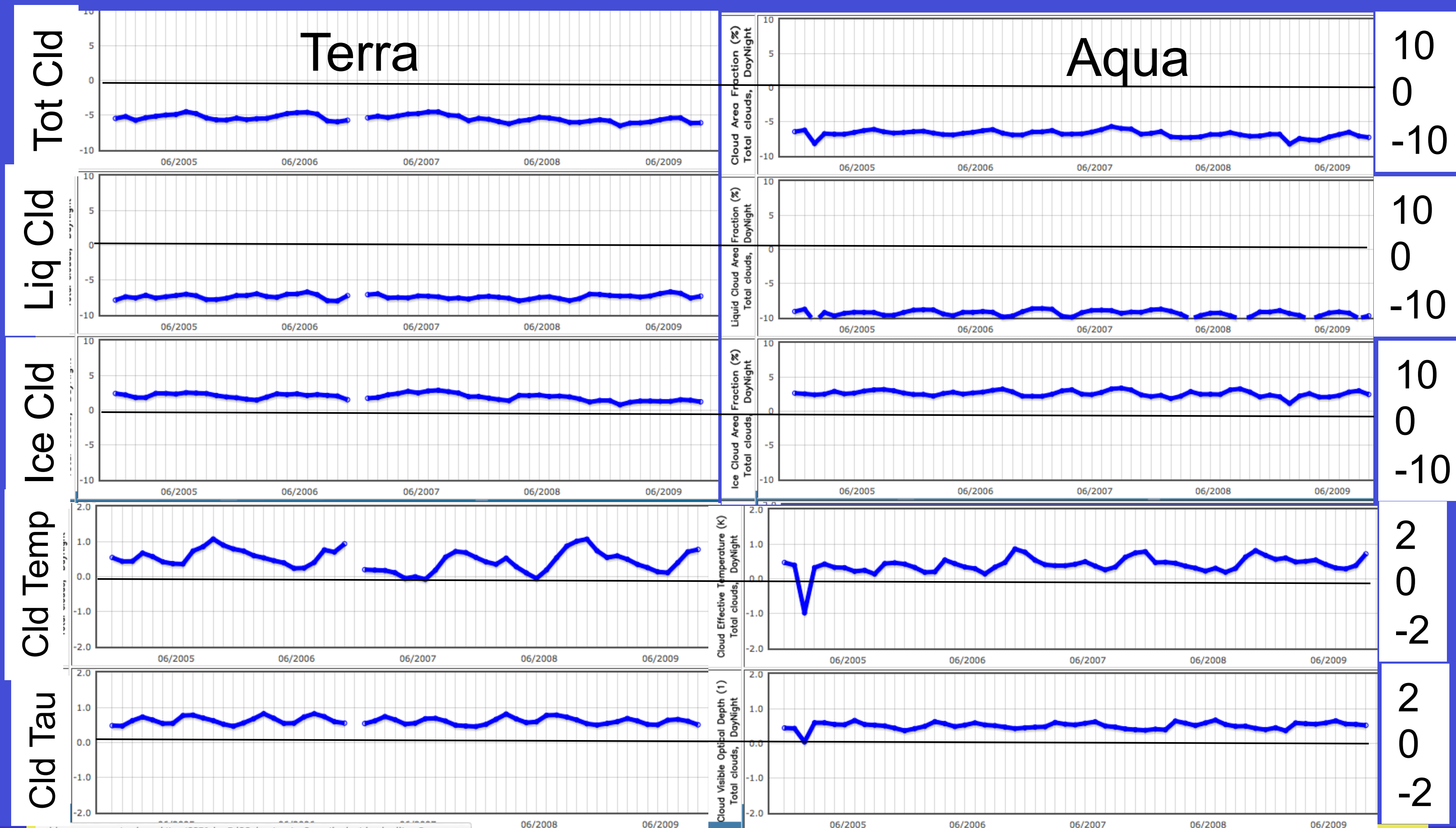
- The Ed3 minus Ed4 all-sky TOA flux is dependent on the CERES instrument calibration and improved ADMs

SSF1deg-Month Ed3 minus Ed4 TOA fluxes



• The Ed3 minus Ed4 clear-sky flux is dependent on the cloud properties

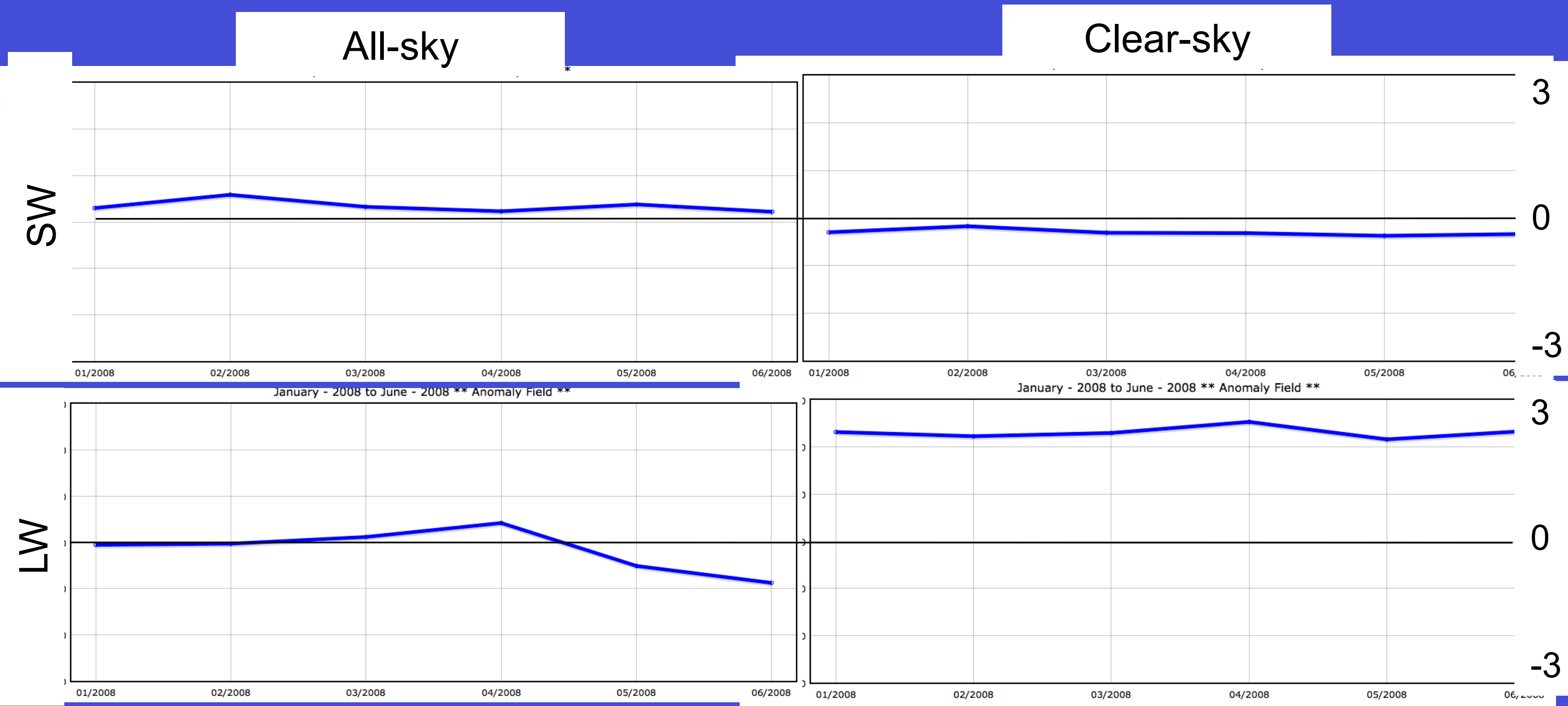
SSF1deg Ed3-Ed4 cloud properties, 2005-2009



- The low cloud amount has increased by 10%, ice clouds reduced by 2%
- Cloud temperature and optical depth have decreased by 0.5K and 0.5

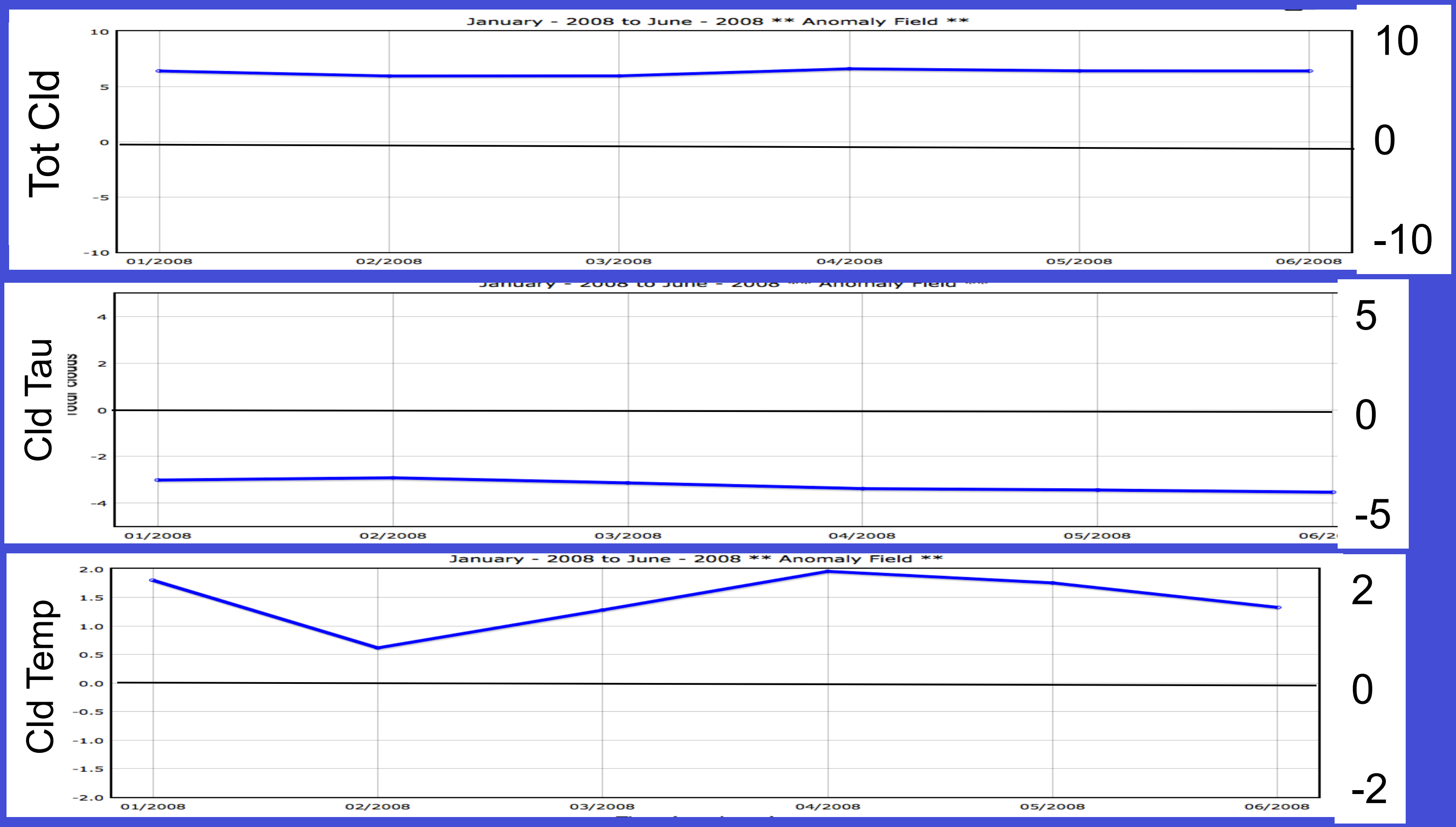
SYN1deg Ed3 – Ed4

SYN1deg-Month Ed4 minus Ed3 TOA fluxes, Jan-Jun 2008



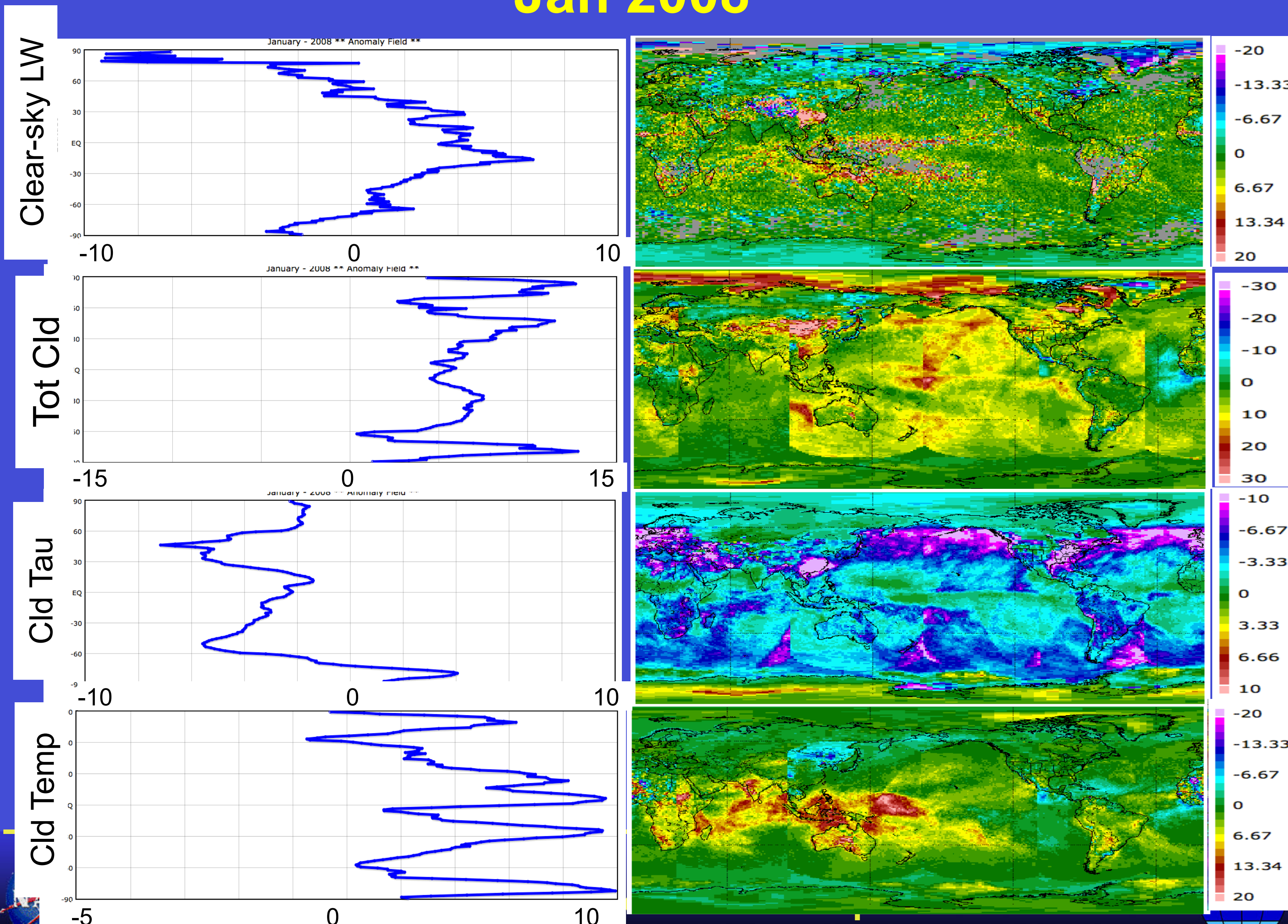
- The Ed4 minus Ed3 SYN1deg is consistent with SSF1deg difference
- The SYN1deg clear-sky LW difference (-2.5Wm-2) is greater than for SSF1deg (-1.5 Wm-2)

SYN1deg-Month Ed4 minus Ed3 clouds, Jan-Jun 2008



- The Ed4 total cloud amount is 6% greater than Ed3, SSF1deg (6%)
- The Ed4 optical depth is -3 less than Ed3, SSF1deg (-0.5)
- The Ed4 cloud temperature is 1K less than Ed3, SSF1deg (-0.5K)

SYN1deg-Month Ed4 minus Ed3 clouds, Jan 2008



TISA Edition 4 deliveries

- GGEO grid is being processed at 6 months/week
  - Near real-time processing projected in mid-March 2016
- Finish validating the SSF1deg and SYN1deg-lite codes this month
  - For Ed4 EBAF TOA flux processing
- Deliver Cldtyphist by October, previously known as ISCCP-D2like
  - CERES MODIS and GEO monthly hourly and monthly cloud properties stratified by optical depth and pressure
  - Compare with the SYN1deg-Mhour dataset, which has been developed and tested since the last the CERES science team meeting
- FluxByCloudTyp product in 2016, new
  - Instantaneous gridded CERES fluxes by cloud type as in CldTypHist, based on sub-footprint MODIS derived broadband fluxes
  - Begin testing the product format with CLARREO users
- Validate the TISA Ed4 products and write DQS
  - Compare products for consistency and with GERB and ScaRaB diurnal fluxes

TISA Future Efforts

- Transfer the GEO calibration reference from Aqua-MODIS to NPP-VIIRS
- Improve the GEO SW narrowband to broadband fluxes
  - Build snow directional models from Ed4 data
  - Use Lusheng's theoretical 32 channel spectral ADMs
  - Use Himawari-8 multiple visible channels
- Improve the TISA code robustness, modularization and scalability for Edition 5